



05/10/99

# UTILITY PATENT APPLICATION TRANSMITTAL

March 26, 1999

Attorney Docket No.:	CM02872J	Total Pages:	2
First-Named Inventor or Application Identifier	CHARLES R. RUELKE		
Title:	<b>Multi-Layered Inductively Coupled Helical Directional Coupler</b>		
Express Mail Label No.:			

(Only for new nonprovisional applications under 37 CFR 1.53(b))

<b>APPLICATION ELEMENTS</b> (see MPEP chapter 600 concerning utility patent application contents)	ADDRESS TO:	Assistant Commissioner for Patents Box Patent Application Washington, D.C. 20231
---	-------------	--

1.	<input checked="" type="checkbox"/>	Fee Transmittal Form <i>in duplicate</i>			
2.	<input checked="" type="checkbox"/>	Specification	Total Pages	19	
3.	<input checked="" type="checkbox"/>	Drawings	Total Sheets:	7	
4.	<input checked="" type="checkbox"/>	Oath or Declaration with Power of Attorney	Total Pages	3	
	a.	<input checked="" type="checkbox"/> Newly Executed (original or copy)			
	b.	<input type="checkbox"/> Copy from prior application (37 CFR §1.63(d)) (for continuation/divisional with Box 17 completed)			
	i.	<input type="checkbox"/> Deletion of Inventor(s): Signed statement attached deleting inventor(s) named in the prior application (see 37 CFR §1.63(d)(2) and 1.33(b))			
5.	<input type="checkbox"/>	Incorporation by Reference ( <i>useable if Box 4b is checked</i> ) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.			
6.	<input type="checkbox"/>	Microfiche Computer Program (Appendix)			
7.	<input type="checkbox"/>	Nucleotide and/or Amino Acid Sequence Submission			

## ACCOMPANYING APPLICATION PARTS

8.	<input checked="" type="checkbox"/>	Assignment Papers ( <i>cover sheet and document(s)</i> )			
9.	<input type="checkbox"/>	37 CFR §3.73(b) Statement (when there is an assignee)	<input type="checkbox"/> Power of Attorney		
10.	<input type="checkbox"/>	English Translation Document ( <i>if applicable</i> )			
11.	<input type="checkbox"/>	Information Disclosure Statement (IDS)/PTO-1449	<input type="checkbox"/> Copies of IDS Citations		
12.	<input type="checkbox"/>	Preliminary Amendment			
13.	<input checked="" type="checkbox"/>	Return Receipt Postcard (MPEP 503) ( <i>should be specially itemized</i> )			
14.	<input type="checkbox"/>	Small Entity Statements			

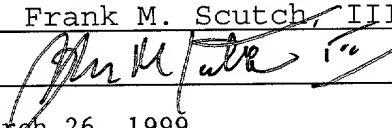
09/307443



05/10/99

15.	<input type="checkbox"/> Certified Copy of Priority Document(s)
16.	<input type="checkbox"/> Other:
17.	<p><b>IF A CONTINUING APPLICATION</b>  <i>check appropriate box and supply the requisite information below  and in a preliminary amendment:</i></p> <div style="display: flex; justify-content: space-between;"> <div> <input type="checkbox"/> Continuation <input type="checkbox"/> Divisional <input type="checkbox"/> Continuation-in-Part (CIP) </div> <div> Prior Application No. _____ </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <div>Prior Appl. information: Examiner:</div> <div>Group/Art Unit:</div> </div>

CORRESPONDENCE ADDRESS					
NAME	Frank M. Scutch, III Attorney for Applicant(s)				
Reg. No.	34,484				
ADDRESS	Motorola, Inc. Intellectual Property Department 8000 West Sunrise Boulevard				
CITY	Ft. Lauderdale	STATE	FL	ZIP CODE	33322
COUNTRY	U.S.A.	TELEPHONE	(954) 723-6449	FAX	(954) 723-3871

SUBMITTED BY	
NAME	Frank M. Scutch, III      Reg. No.    34,484
SIGNATURE	
DATE	March 26, 1999      Deposit Account    13-4774-1740 User ID

## Multi-Layered Inductively Coupled Helical Directional Coupler

5

### Technical Field

10 This invention relates in general to two-way radios and more particularly to RF power coupling.

### Background

15 Radio Frequency (RF) Coupling networks are well known in the art and are used in many different applications. These applications include transmit power control, radar detection and control, isolation and feedback strategies. Particular to the portable radio, coupler designs are critical to optimizing transmit output power while providing protection to the transmit power amplifier. A properly designed coupler will provide differentiation between incident and reflected RF energy (directivity) while exhibiting uniform coupling efficiency over the desired RF frequency range. The physical design of  
20 the coupler must accommodate well understood relationships between RF voltage potentials and their associated electric fields, and RF current densities and its associated magnetic fields. Both magnetic (H-field) and electric fields (E-field) are present in a propagating RF signal; however, the coupler's physical design can be constructed to primarily operate off either field (electric or magnetic) as the fundamental coupling  
25 mechanism. The relationship between the two fields are defined by a family equations known as Maxwell's equations. The electromagnetic vector relationships germane to this discussion are shown in Table 1 below:

TABLE 1

5             $S = E \times H$        where      S = Power per unit area ( $\text{W/m}^2$ )-Poynting Vector  
    E = Electric Field Intensity Vector  
    H = Magnetic Field Intensity Vector  
  
and

10  $\nabla \times \mathbf{H} = \mathbf{J} + \partial \mathbf{D} / \partial t$ ;  $\mathbf{H}$  = Magnetic Field Intensity Vector  
 $\mathbf{J}$  = Current Density Vector  
 $\mathbf{D}$  = Magnetic Flux Density  
 $\partial / \partial t$  = time derivative

From Maxwell's equations, it is shown that a time varying electric and magnetic field generated by RF current densities or voltage potentials applied to a transmission line induce electromagnetic (EM) fields in the surrounding region. If a second conductor is positioned within the region, the magnetic field (H-field) will induce a current vector  $J$  proportional to the conductor's surface area which is perpendicular to propagating EM fields

The vector direction of the induced field is determined by the Poynting Vector  $S$ . This principle holds true for both co-planar and offset structures that are positioned on different planes from the main transmission line. By using the "Right Hand Rule" to  $S$ , the direction of the current flow within a given conductor can be determined by rotating the index finger of the right hand from the E-field vector to the H-field vector, and noting that the extended thumb points in the direction of the current flow. A diagram of a transmission line with a coupling structure positioned in an upper plane (not directly over) the main transmission line is shown in FIG. 1.

Prior art FIG. 1 shows the top surface of the transmission line 101 exhibits a magnetic field polarity that is “additive” to the H-field of the lower surface Upper Plate 100 (coupling structure). For this condition to exist, the induced current “ $i_o$ ” in the upper plate 100 must flow in the OPPOSITE direction of the current “ $i_l$ ” in transmission line 101. If the plate current were “forced” to flow in the same direction as the transmission line current, the H-fields between the transmission line and the plate would tend to “cancel” each other and coupling efficiency would be degraded. Thus, any geometry that enhances the coupler structure performance based on magnetic field coupling must provide complementary magnetic fields with the same polarity as that distributed on the transmission line.

It is also apparent from FIG. 1 that E-fields are perpendicular to the H-field. Thus, for the E-fields to couple efficiently, the coupling structure should “overlap” the transmission line to maximize the conductor surface area which is perpendicular to the E-fields. This method of coupling can be described as Capacitive coupling (or broad edge coupling). This is different from a structure that utilizes magnetic field coupling, since maximizing perpendicular surface area to the H-field only requires a parallel structure to the transmission line, it does not necessitate overlap. These principles hold true for any three-dimensional (3-D) structure, including those which may be embedded into a PC board.

FIG. 2 illustrates a 3-D multi-plane coupling structure of the prior art with the associated upper and lower plate current vectors (“ $i_0$ ” and “ $i_2$ ” respectively) and H-field polarities that are additive to the corresponding transmission line 201. It is important to note that the H-field polarity of the lower surface of upper plate 200 CONFLICTS with the top surface polarity of lower plate 202. Thus, regions where the upper and lower plate overlap will cause reduced coupling efficiency, due to H-field cancellation, if they are electrically connected together (i.e.: Current flows in the same direction in both structures). It is therefore imperative that the multi-layered helical geometry minimize regions of overlap between differing planes having current vectors oriented in the same direction.

From the foregoing discussion, it is evident that the two fields (E-field and H-field) are complementary, but independent mechanisms that can be used to provide coupling of RF energy. The electromagnetic relationship between them is determined by Maxwell’s equations, which form guidelines that must be met to maximize coupling efficiency while providing superior directivity.

Directivity is a measure of the reflected and incident field differentiation of a coupler. The algebraic difference in decibels (dB) of the forward and reverse coupling coefficients for any fixed structure is defined as the directivity of that structure. A 20dB directivity factor is considered acceptable for a bi-directional coupler. Historically, high performance bi-directional couplers have been fabricated on a substrate such as alumina, with thin film processes and their tight tolerance capability defining the coupler geometries to achieve a controlled 20 dB coupling coefficient with greater than 20dB of directivity. Although the modularized approach to implementing the coupler is effective, it adds cost and process steps that could otherwise be eliminated if the coupler were to be embedded into the PCB itself. To achieve high reliability coupler performance with

existing PCB make tolerances of  $\pm 2$ mil gaussian width distributions requires an innovative design approach. This innovation is based on selecting the proper coupling mode (E-field or H-field) that provides a design meeting manufacturing and performance requirements, while minimizing cost and area. Therefore, the need exists for embedded  
5 PCB coupler structure which achieves these desired objectives.

### Brief Description of the Drawings

FIG. 1 is a profile view of magnetic & electric field polarities for single plate  
10 coupler structure & main transmission line used in the prior art.

FIG. 2 is a profile view of magnetic & electric field polarities for multi-plane coupler structure & main transmission line used in the prior art.

FIG. 3 is a 3-dimensional profile view of the preferred embodiment of the invention, illustrating a planar helix structure wrapped around the main transmission line  
15 with secondary coupling appendages parallel to the transmission line.

FIG. 4 is a top view of helix structure of FIG. 3 (YAG Structure).

FIG. 5 is a top view of a helix structure with parallel structure within the Z plane at vias. (C Structure).

FIG. 6 is a top view of a second embodiment of the invention maximizing parallel  
20 coupling surface area within the XY plane embedded within a multi layered Helix structure. (BOW Structure).

FIG. 7 is a side view of the multi-layer structure showing dielectric thickness and plane designation of the helix structure shown in FIGs. 3 through 6.

FIG. 8 is a 3-dimensional profile view of yet another embodiment of the invention,  
25 illustrating a continuous helix structure wrapped around the main transmission line with secondary coupling elements parallel to the transmission line.

### Detailed Description of the Preferred Embodiment

30 The focus of this discussion is to detail a methodology of magnetic field coupling and the associated geometric constraints. A summary of the electrical constraints that maximize magnetic field coupling is listed below.

1) The maximally efficient inductive structure is a closely wound helical where H-fields from contiguous windings are additive. This structure provides the smallest (most spatially efficient) three-dimensional resonant structure and can be used to induce a band pass coupling response.

5        2) For multi-layer planar structures, minimize H- field cancellation by minimizing overlap between coupling structures that are also electrically connected to each other.

3) Since current densities are maximal at the EDGES of a planar transmission line, maximum H-field coupling and directivity performances achieved by maximizing the coupling structure's EDGE surface area that runs PARALLEL to the main transmission  
10 line.

4) Ensure that overall current flow induced onto coupling structure is not "folded back" onto itself by utilizing structures that have 180° discontinuities within the same plane.

Some of these guidelines may tend to conflict with each other (i.e.: #1 & #3  
15 above); however, optimization for best performance is still realizable. This is achieved by adopting a helix as the basic geometric structure used in the coupler, but with sufficient space between contiguous windings to allow secondary structures to be embedded to maximize the magnetic (H-Field) coupling mode. Since planar structures are configured based on the frequency of operation, spatial requirements and desired performance for a  
20 given application, a final element of the embodiment includes series lumped element components as resonant elements. In summary, the overall concept as disclosed in this invention is:

•the implementation of unique multi-planar geometry(s) incorporating a helix topology "wrapped" around main transmission line (Helix with transmission line running  
25 down center axis), which is adaptable to being embedded into a RF PCB:

• Coupling plates embedded into helix to maximize magnetic field (inductive) mode coupling; and

• Series lumped element capacitor to achieve band pass resonant response; also serves as a dc block (from rectifying diode)

30 Referring now to the preferred embodiment shown in FIG. 3, a stripline transmission line 301 is positioned along the center axis of a multi-planar helical structure comprised of upper plate 300 and lower plate structures 302 electrically connected together by a series of vias 303. Structures 300, 301, and 302 are all on different planes, each plane separated by a dielectric material with characteristic impedance and velocity

factor characteristics selected for the particular RF application. FIG. 7 illustrates this planar relationship for stripline structures, with structures 300, 301, and 302 of FIG. 3 being located on Layer 1, Layer 2 and Layer 3 of FIG. 7 respectively. The ground planes (not shown) are positioned above and below the entire structure in compliance with classical stripline techniques. Note that passive elements equivalent to 304 and 305 of FIG. 3 are not shown in FIG. 7. For classical microstrip transmission line designs, a single ground plane (not shown) is positioned below lower plate structures 302 and air dielectric is used above the transmission line 301; thus the upper plate structures 300 are functionally "air bridges" over transmission line 301.

Transmission line 301 is generally attached to an RF source such as an RF power amplifier (not shown) and provides for efficient propagation of RF energy within a specific frequency range to subsequent stages such as harmonic filters (also not shown). As RF power is transmitted down the main transmission line, EM near-fields are generated which are coupled to adjacent structures 300 and 302. The physical dimension of the transmission line 301 is determined through classical methods dependent on substrate dielectric constants, desired characteristic impedance, and distance from ground planes (not shown). The physical dimensions of upper and lower coupling plates 300 and 302 are set to minimize capacitive (E-field) coupling; thus overlap with either the main transmission line or with subsequent interconnected plates are minimized. This means that the coupling plates are generally thin with respect to the transmission line (high impedance) and designed to maximize surface area parallel to the main transmission line (perpendicular to the H-field) through using secondary appendages or geometric structures. The number of turns of the helix structure is set by the coupling factor and frequency of operation required for the given application. The greater the number of turns for a given frequency, the greater higher the coupling factor. The higher the frequency of operation, the lower the number of turns required for a given coupling factor.

The direction of the power detected for the coupler is determined by the location of the terminating impedance (for example the resistor 305 in FIG. 3). Given forward RF power is defined as propagating along the transmission line 301 from left-to-right as indicated in FIG. 3, then coupled RF energy proportional to the forward power will propagate through capacitor 304 when terminating resistor 305 is positioned as shown in FIG. 3. If the relative positions of capacitor 304 and resistor 305 is swapped, then the coupled RF energy at capacitive element 304 will be proportional to an incident wave propagating from right-to-left (Reflected or reverse power detection). For both forward



and reverse power detection applications, the basic geometric constraint for the helix are the same.

As illustrated in FIG. 3, a series of vias 303 are employed to interconnect the upper and lower plates 300 and 302 to provide electrical connectivity to the entire helix coupling structure. The distance from the vias to the edge of the main transmission line is determined by the plane of intersection between the H-field and the helix structure. Although this relationship will be explored in further detail herein, it should be noted that in some geometries, the via connection 303 themselves can be considered as perpendicular "flanges" in the Z-plane to the H-field vectors in the XY-plane (vias 303 perpendicular to H-Field of transmission line 301). This will be explored further in subsequent descriptions.

In general, all multi-layered helix structures must be interconnected to form the proper geometry, which in turn must be attached to a terminating impedance and to a series capacitive element (lump or distributed) as shown in FIG. 3. The frequency response of the coupler is determined by the intrinsic inductance of the helix, and the series lump element capacitor. Directivity is "peak" in the frequency band of operation, providing optimum performance. The series capacitor also may serve as a dc block capacitor for external transmitter circuits that require a particular bias.

Referring to FIG. 4, the interrelationship between the helix structure, secondary flanges, and main transmission line 401 can be clearly seen. This top view of FIG. 3 shows that the horizontal separation 408 between the flange edge and the transmission line 401 is minimal without overlapping each other. The distance 404 from the transmission line edge to vias 403 is significantly larger than flange separation 408. And since near field coupling efficiency is inversely proportional to the distance between the source (transmission line 401) and receptor, the flanges embedded into the upper and lower plates 400 and 402 are the primary coupling structure over the vias. The length of the flange segments 405, 406, and 407 are determined by geometric spacing of the interconnecting vias 409 and the frequency of operation.

It should be noted that in this embodiment, the flanges are variable length to maximize coupling bandwidth and that the upper and lower plate flanges do not overlap each other. It will be evident to those skilled in the art, that variable number of flanges (greater than one) can be used and the flange length 405, 406, and 407 can be varied from this embodiment and still functionally maintain the integrity of the helix structure. The dielectric thickness between the planes containing lower plates 402, transmission line 401

and upper plates 400 are determined by standard PCB manufacturing process and desired coupling efficiency, understanding that thinner dielectric thickness (closer proximity between transmission line and coupling plates) increase coupling efficiency for reasons previously discussed. The illustration of the multi-layered structure is shown in FIG. 7.

- 5 This coupling structure provides H-field coupling in the XY plane primarily through the flange extensions. As previously discussed, capacitive and resistive terminations may be positioned at terminals 3 and 4 to functionally differentiate the direction (incident or reflected) of the RF energy being conducted on transmission line 401.

- Referring to FIG. 5, a second or alternative embodiment of the invention is disclosed. Here, no parallel structures are evident in the XY plane between transmission line 501 and upper and lower plate structures 500 and 502. However, the transmission line 501 is offset to one side to provide close proximity to the family of vias 503. Distance 505 is significantly smaller than distance 504 (proximity to family of vias 506). Thus the H-field radiation in the XY plane is perpendicularly bisected by vias 503 in the Z-plane.
- 15 Distance 505 is set by PCB manufacturing tolerances and the desired level of coupling efficiency required for the given application. The geometry in FIG. 5 has the further advantage of minimizing capacitive coupling by minimizing the overlap surface area between coupling plates 500 and 502 and transmission line 501. The distance between each via 509 is determined by the desired arch-length of the interconnecting coupling plates 500 and 502, and the desired coupling coefficient. The greater the number of vias per unit length of transmission line 501, the higher the coupling factor.
- 20

- It should be further noted that distance 504 should be large compared to distance 505, to avoid degradation of coupling efficiency and directivity. This degradation results from opposing H-Field induce in the upper and lower plate 500 and 502 that meet at via connection 506. As distance 504 is reduced, the upper and lower plate region at vias 506 tend to become parallel to transmission line 501, increasing the current density  $J$  induced on each plate by the H-Field. However, the H-field vector at the bottom of upper plate 500 opposes the H-field vector at the top lower plate 502. These two opposing fields are electrically connected together at via 506, thereby reducing the coupling efficiency. This is clearly illustrated in FIG. 2 while visualizing the upper and lower plates 200 and 202 connected end-to-end through a series of vias. This condition does not exist at via connections 503, as the upper and lower plate H-fields are additive, and are also located at the point of highest current density (closest proximity to transmission line 501).
- 25
- 30

In yet another embodiment shown in FIG. 6, a coupling structure contains flange structures “embedded” into the upper and lower plates 600 and 602. FIG. 6 illustrates a helix coupler that bisects the H-field in the XY plane utilizing unique plate geometries to provide maximal surface area parallel to the transmission line 601 (orthogonal to the H-field). As in the previous embodiments, the upper and lower plates are interconnected through vias 603 so as to create an overall helix structure around the main transmission line 601. This coupler design is a variation of the previously discussed “yag coupler” shown in FIG. 4. The modification in this embodiment eliminates the “open stub” effect in the Yag-coupler, which creates high voltage densities at the open end of the flange with no connectivity to provide for current flow. By minimizing the open stub in the coupler structure, the overall coupler resistivity as seen by the induced current is reduced. This improves coupling efficiency and directivity of the coupler structure.

As in the previous embodiments, the distance between vias 609 is determined by manufacturing tolerances, desired coupling efficiency, and frequency of operation (which sets the number of turns in the helix). The width of transmission line 601 is determined using classical stripline or transmission line calculations dependent on substrate dielectric constant, desired characteristic impedance, and distance to nearest ground planes. The substrate geometry is equivalent to the previously discussed embodiments and is illustrated in FIG. 7. The length 604, 605 and 606 of each parallel segment embedded within the upper and lower plates 600 and 602 is set by via separation 609 and angle of intersection 607. It should be apparent to those skilled in the art that variations of the plate geometry can be achieved that changing the relative angle of 607 so that the lengths 604, 605 and 606 are varied, while still maintaining the integrity of the proposed embodiment.

Another possible embodiment of this invention is applicable to non-planar structures. Referring FIG. 8, a transmission line or wire 801 is suspended in a dielectric such as air. A semi-rigid, continuous helix structure 800 is wrapped around the transmission line 801 to support secondary coupling element 802. These coupling elements are parallel to the transmission line and may be of varying lengths 804, varying quantity, or separation 803, depending on the application, frequency of operation, or desired performance. The coupling elements 802 are connected together through helix structure 800, which is electrically conducting. Termination elements 805 and 806 are positioned at the terminals of the helix to provide directional differentiation of the RF

energy traveling along transmission line 801. This is similar to the techniques described in the previous embodiments.

While the preferred embodiments of the invention have been illustrated and described, it will be clear that the invention is not so limited. Numerous modifications incorporating combinations of the disclosed embodiments, changes, or variations, substitutions and equivalents of other geometries will occur to those skilled in the art without departing from the spirit and scope of the present invention as defined by the appended claims.

What is claimed is:

**Claims**

1. A device for coupling RF energy from a transmission line to a plurality of couplers comprising:
- 5       at least one transmission line for carrying energy from a radio frequency (RF) source;
- a plurality of interconnecting upper plates distributed above the transmission line whose dimension extends laterally beyond the width of the transmission line;
- a plurality of interconnecting lower plates distributed below the transmission line
- 10       whose dimension extends laterally beyond the width of the transmission line;
- a plurality of vias positioned to sequentially connect an end of individual upper plates to individual lower plates so as to form a helix structure centered around the transmission line;
- a plurality of secondary plates embedded into the helix structure which are parallel
- 15       to the transmission line;
- at least one capacitive element electrically connected to one end of aforementioned helix structure;
- at least one resistive element electrically connected to an opposite end of the helix structure from the at least one capacitive element; and
- 20       a ground layer positioned below the plurality of interconnecting lower plates and above the plurality of interconnecting upper plates.
2. A device as in claim 1, wherein the at least one transmission line, at least one forward coupler, and at least one reverse coupler are a microstrip.
- 25       3. A device as in claim 1, wherein the at least one transmission line, at least one forward coupler, and at least one reverse coupler are a stripline.

4. A multi-element directional coupler used with a multi-layer printed circuit board comprising:

- 5       a first coupling structure connected to a radio frequency source;
- a plurality of second coupling structures positioned above the first coupling structure for coupling radio frequency (RF) energy;
- a plurality of third coupling structures positioned below the first coupling structure for coupling RF energy;
- 10       a plurality of vias for connecting individual segments of the plurality of second coupling structures with individual segments of the plurality of third coupling structures so as to form a helix structure with axis of rotation centered around the first coupling structure;
- a plurality of secondary plates embedded into the plurality of second coupling structures;
- 15       a plurality of secondary plates embedded into the plurality of third coupling structures;
- a ground layer positioned above the plurality of second coupling structures for providing isolation; and
- 20       a ground layer positioned below the plurality of third coupling for providing isolation.

5. A multi-element directional coupler according to claim 4, wherein the first coupling structure is a RF transmission line.

- 25       6. A multi-element directional coupler according to claim 5, wherein the RF transmission line is a stripline.

7. A multi-element directional coupler according claim 5, wherein the RF transmission line is a microstrip.

- 30       8. A multi-element directional coupler according to claim 4, wherein the helix structure is a forward power coupler.

9. A multi-element directional coupler according to claim 8. wherein the helix structure is an reverse power coupler.

5 10. A multi-element directional coupler according to claim 4, wherein the plurality of secondary plates embedded into the plurality of second coupling structures are positioned parallel with the first coupling structure.

10 11. A multi-element directional coupler according to claim 4, wherein the plurality of secondary plates embedded into the plurality of third coupling structures is positioned parallel with the first coupling structure.

CM02872J

12. A radio frequency (RF) power coupling device comprising:
- at least one transmission line for conducting RF energy;
  - a first plurality of upper connecting structures positioned above the at least one transmission line for providing connectivity for coupled RF energy traveling on the at least one transmission line;
  - a second plurality of lower connecting structures positioned below the at least one transmission line for providing connectivity for coupled RF energy traveling on the at least one transmission line;
  - a plurality of vias for connecting individual segments of the first plurality of upper connecting structures with individual segments of the second plurality of lower connecting structures so as to form a helix geometric structure;
  - a first ground layer positioned above the plurality of upper connecting structures for isolating the at least one transmission line and the plurality of upper connecting structures; and
  - a second ground layer positioned below the plurality of lower connecting structures for isolating the at least one transmission line and the plurality of lower connecting structures; and
  - wherein at least one of via of the plurality of vias is positioned a predetermined distance from the transmission line for increasing coupling between the at least one transmission line and the helix structure;

13. A radio frequency power coupling device as in claim 12, wherein the at least one transmission line, first plurality of upper connecting structures and second plurality of lower connecting structures are planar structures.

14. A radio frequency power coupling device as in claim 12, wherein the at least one transmission line is a microstrip, first plurality of upper connecting structures are air bridges and second plurality of lower connecting structures are strip line.

15. A radio frequency power coupling device as in claim 12, wherein the at least one transmission line, first plurality of upper connecting structures and second plurality of lower connecting structures are a stripline.



16. A radio frequency power coupling device as in claim 12, further comprising:  
at least one secondary structure embedded into the plurality of upper  
connecting structures each positioned a predetermined distance from the at least one  
transmission line, for increasing coupling between the at least one transmission line and  
5 helix geometric structure.

17. A radio frequency power coupling device as in claim 12, further comprising:  
at least one secondary structure is embedded into the plurality of lower  
connecting structures, each positioned a predetermined distance from the at least one  
10 transmission line, for increasing coupling between the at least one transmission line and  
helix geometric structure ;

18. A radio frequency power coupling device as in claim 17, further comprising:  
at least one secondary structure is embedded into the plurality of lower  
15 connecting structures, each positioned a predetermined distance from to the at least one  
transmission line, for increasing coupling between the at least one transmission line and  
helix geometric structure.

19. A radio frequency power coupling device as in claims 16, 17 or 18 wherein the  
20 at least plurality of upper connecting structures and plurality of lower connecting  
structures are planar.

20. A radio frequency power coupling device as in claim 16, 17 or 18 wherein the  
secondary structure which is embedded into the plurality of connecting structures is  
25 parallel with the at least one transmission line, for increasing coupling between the at least  
one transmission line and helix geometric structure

21. A radio frequency power coupling device as in claim 16, 17, or 18 wherein the  
at least one transmission line is positioned on a first substrate.  
30

22. A radio frequency power coupling device as in claim 20, wherein the plurality  
of upper connecting structures is positioned on a second substrate.

23. A radio frequency power coupling device as in claim 21, wherein the plurality of plurality connecting structures is positioned on a third substrate.

5 24. A radio frequency power coupling device as in claim 22, wherein the second substrate and the third substrate are asymmetrically positioned a predetermined distance from the first substrate.

25. A method of increasing the coupling coefficient of a directional coupler device which includes at least one transmission line and at least one magnetic field coupling device comprising the steps of:

- 5       positioning an upper interconnecting structure in a second plane parallel to and above plane with the transmission line;
- positioning a lower interconnecting structure in a third plane parallel to and below plane with the transmission line;
- aligning at least one magnetic field coupling structure at a predetermined distance from and parallel to the at least one transmission line;
- 10       electrically interconnecting the at least one magnetic field coupling device with the upper or lower interconnecting structure; and
- electrically interconnecting the upper and lower interconnecting structure using at least one via.

- 15       26. A method as in claim 25, wherein the at least one magnetic field coupling device is a forward power coupler.

27. A method as in claim 25, wherein the at least magnetic field coupling device is a reverse power coupler.

- 20       28. A method as in claim 25, wherein the at least one transmission line is a microstrip, upper interconnecting structures are air bridges and second plurality of lower interconnecting structures are strip line.

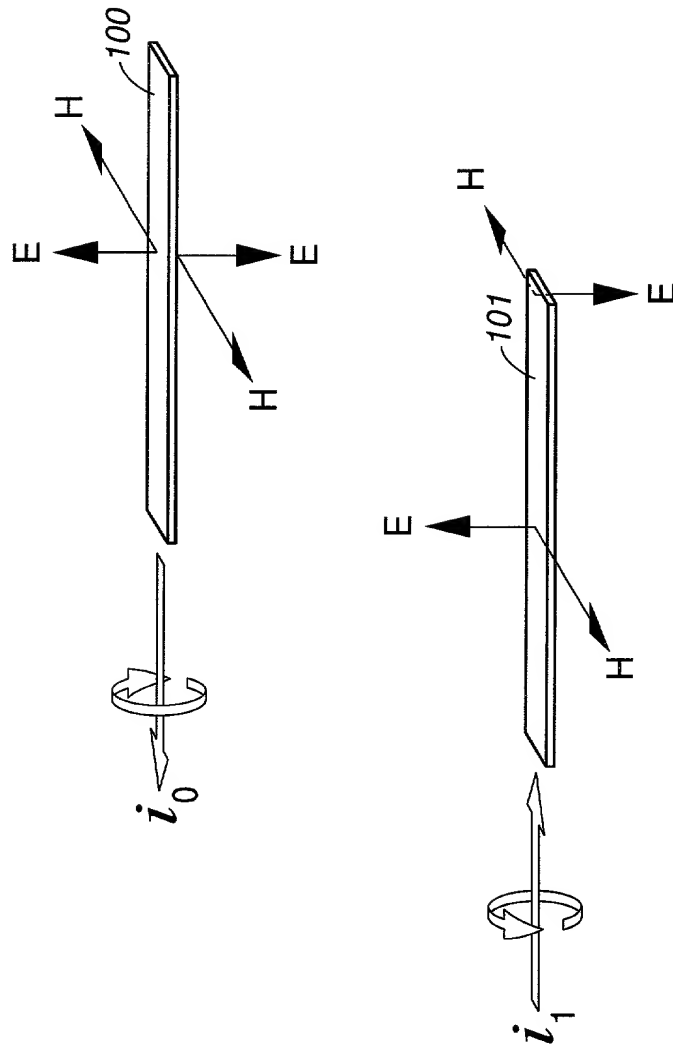
- 25       29. A method as in claim 25, wherein the at least one transmission line, upper interconnecting structures and lower interconnecting structures are a stripline.

30. A radio frequency (RF) power coupling device comprising:  
at least one transmission line for conducting RF energy;  
a helix structure with a plurality of windings positioned such that the  
transmission line is located along the helix structure axis of rotation; and  
5 a plurality secondary structures connected to the helix structure and  
positioned parallel to the at least one transmission line at predetermined distances from  
transmission line.
31. A radio frequency power coupling device as in claim 31, wherein the plurality  
10 of secondary structures are of variable length.

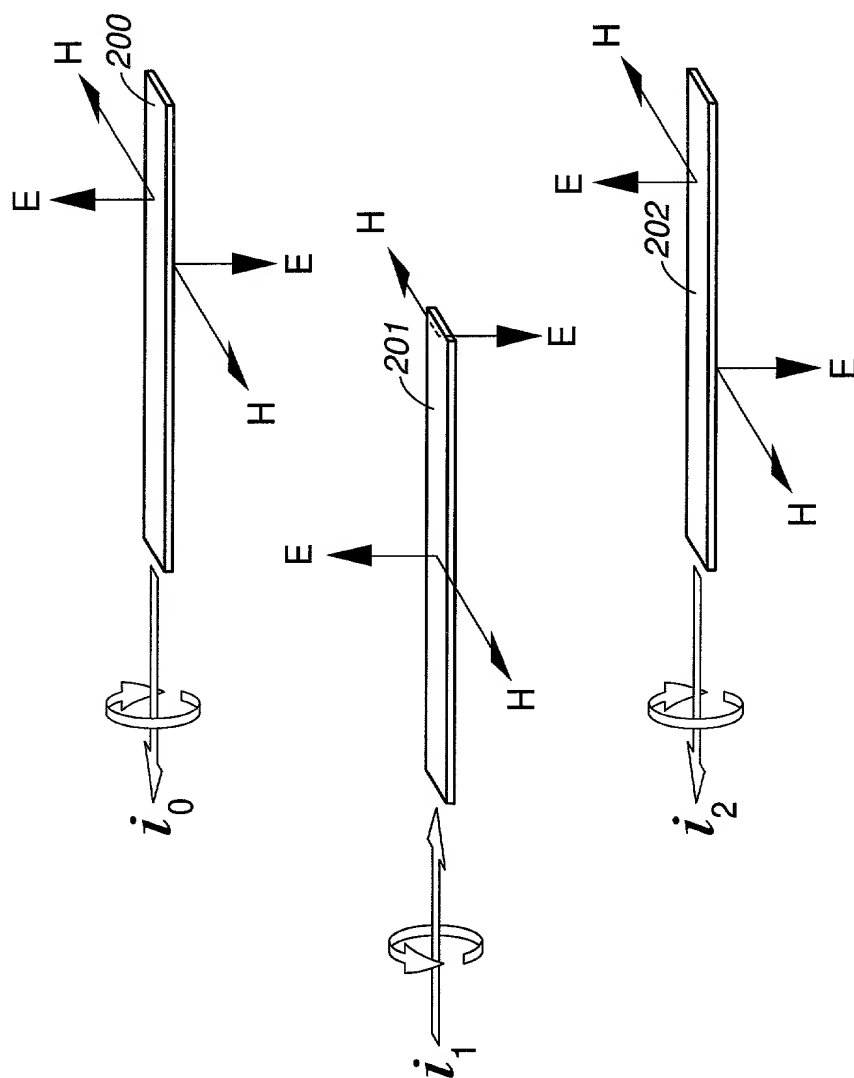
## **Multi-Layered Inductively Coupled Helical Directional Coupler**

### **5 Abstract of the Disclosure**

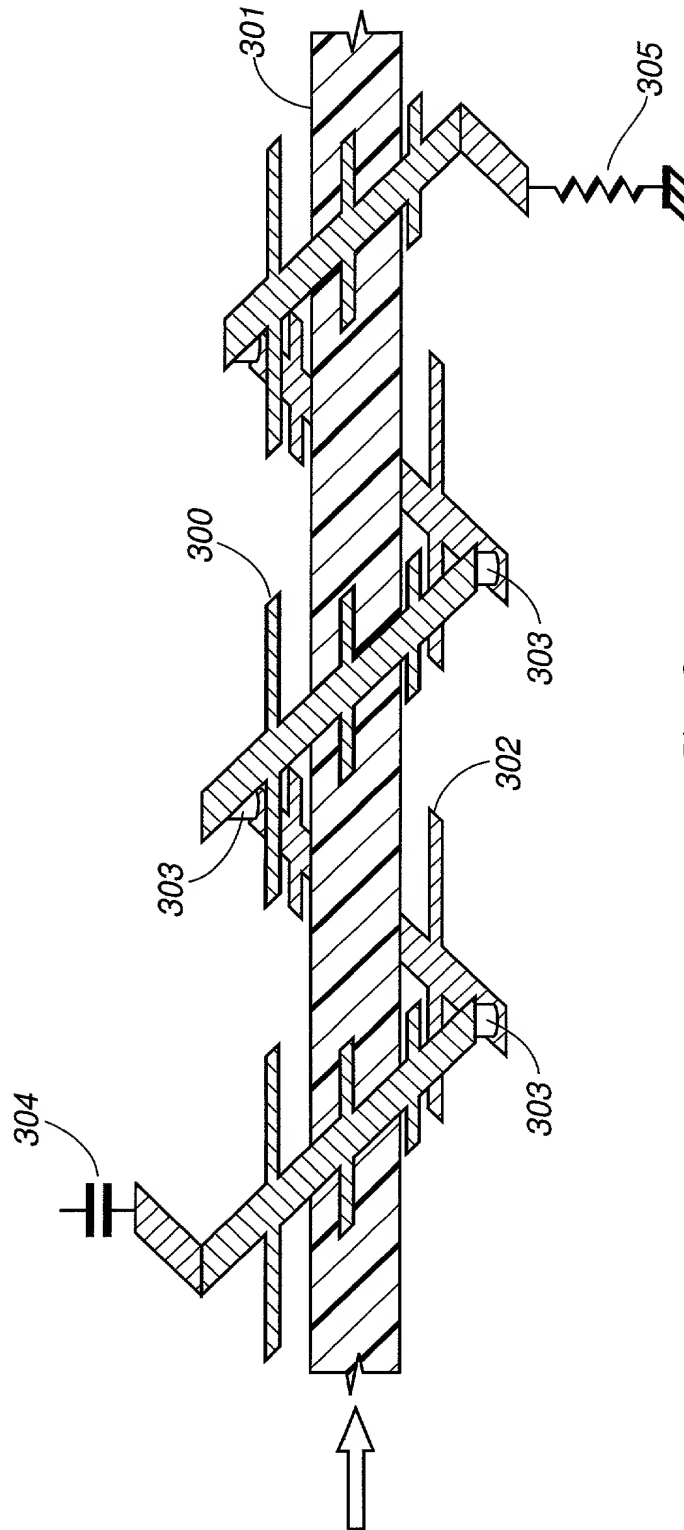
A coupling device in FIG. 3 consisting of upper and lower connecting plates 100 and 101 with external flanges parallel to transmission line (103) for coupling RF energy for forward power detection. The coupling device (100) incorporates a helix structure with rotation centered near or about transmission line 103 and incorporates embedded  
10 secondary structures which are parallel to transmission line and fixed a predetermined distance from the transmission line (103). These plurality of parallel flanges are used to increase the coupling coefficient and directivity of the helix coupler (107) and maintain geometries that optimize magnetic field coupling . One or more vias (102) are used to connect individual upper connecting plate (100) and individual lower connecting plate  
15 (101) to form the overall helix structure. The addition of the parallel flanges to upper and lower connecting plates allow for a greater coupling efficiency per unit length of transmission line 103.



**FIG. 1**  
(PRIOR ART)



**FIG. 2**  
(PRIOR ART)

**FIG. 3**

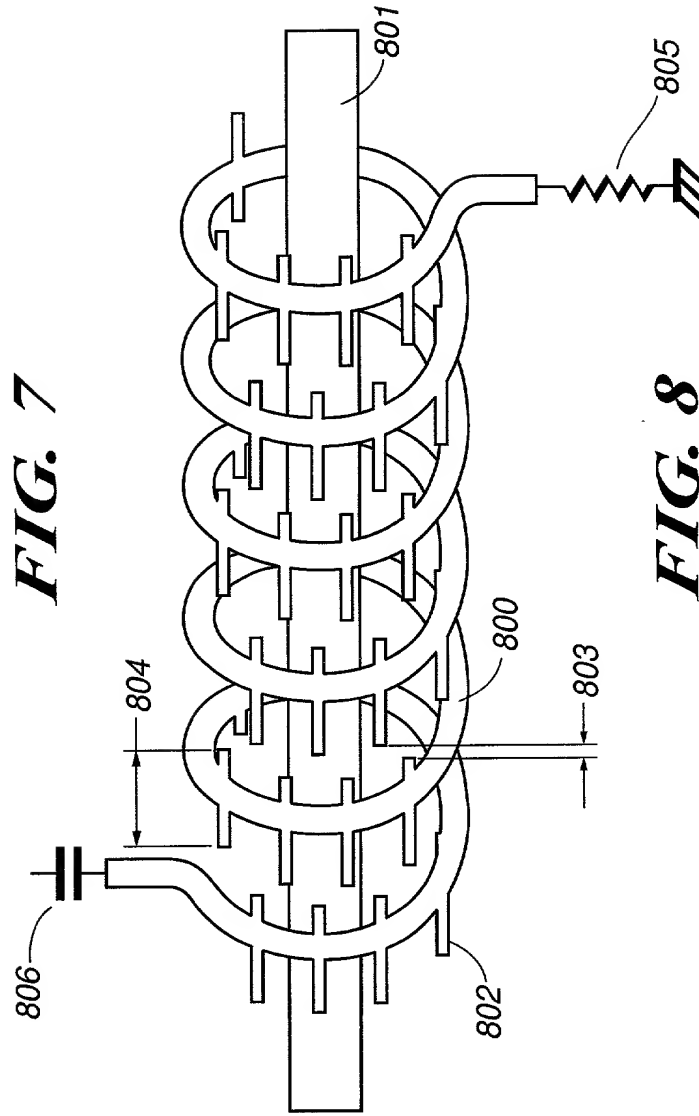
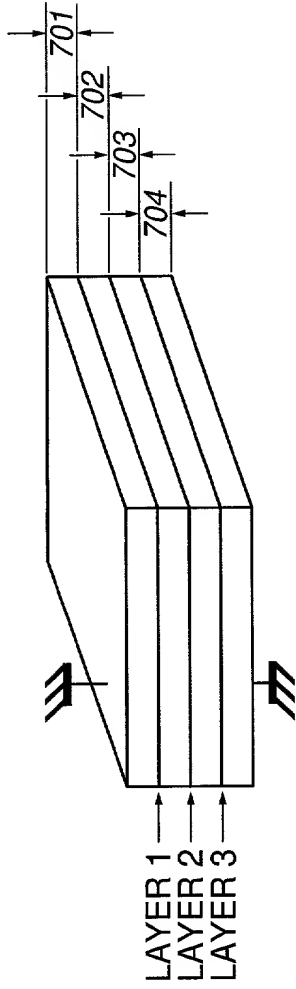






**FIG. 5**





PATENT APPLICATION DECLARATION  
COMBINED WITH POWER OF ATTORNEY

Attorney's Docket No.: CM02872J



Regular (Utility)



Design Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**Multi-Layered Inductively Coupled Helical  
Directional Coupler**

the specification of which:



is attached hereto



was filed on: \_\_\_\_\_

as U.S. Serial No.: \_\_\_\_\_

and was amended on \_\_\_\_\_

*(if applicable)*

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d), of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign/PCT Application(s):



no such application(s) filed



such application(s) identified as  
follows:

Application Number	Country	Date of Filing (day, month, year)	Priority Claimed Under 37 U.S.C. 119
			<input type="checkbox"/> Yes <input type="checkbox"/> No
			<input type="checkbox"/> Yes <input type="checkbox"/> No

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

Provisional Application Serial No.: \_\_\_\_\_

Provisional Application Filing Date: \_\_\_\_\_

I hereby claim the priority benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which is material to the examination of this application and which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Prior U.S. Application(s):



no such application(s) filed



such application(s) identified as follows:

Application No.	Filing Date (day, month, year)	Status (Patented, Pending, Abandoned)

I HEREBY APPOINT THE FOLLOWING AS MY ATTORNEY(S) OR AGENT(S)  
WITH FULL POWER OF SUBSTITUTION TO PROSECUTE THIS APPLICATION  
AND TRANSACT ALL BUSINESS IN THE PATENT AND TRADEMARK OFFICE  
CONNECTED THEREWITH:

NAME(S)	REG. NO.(S)	ASSOCIATE POWER OF ATTORNEY ATTACHED	
Daniel K. Nichols	29,420	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Val Jean F. Hillman	34,841	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Frank M. Scutch, III	34,484	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Lesley A. Rhyne	34,909	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Andrew S. Fuller	37,328	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Dale W. Dorinski	35,122	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
M. Mansour Ghomeshi	35,155	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Barbara R. Doutre	39,505.	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Scott M. Garrett	39,988	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
Felipe J. Farley	38,445	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No

Send correspondence to:

Motorola, Inc.  
Intellectual Property Law Section  
8000 West Sunrise Boulevard  
Fort Lauderdale, Florida 33322

Attention: Frank M. Scutch, III

Direct telephone calls to: (954) 723-6449  
Direct faxes to: (954) 723-3871

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of first-named or sole inventor <u>CHARLES R. RUELKE</u>		
Inventor's signature <u>Charles R. Ruelke</u>	Date <u>1/26/99</u>	
Residence <u>PLANTATION</u>	FLORIDA	
City	State or Foreign Country	
Citizenship <u>U.S.A.</u>	Country	
Post Office Address <u>384 NW 87TH TERRACE</u>	Street Address	
<u>PLANTATION</u>	<u>FLORIDA</u>	<u>33324</u>
City	State or Country	Zip Code

Full name of second-named joint inventor _____		
Inventor's signature _____	Date _____	
Residence _____	State or Foreign Country	
City		
Citizenship _____	Country	
Post Office Address _____	Street Address	
City	State or Country	Zip Code